COLORED STONES
ASSIGNMENT 5

SPECIFIC GRAVITY AND OTHER PHYSICAL PROPERTIES IN IDENTIFICATION

IDENTIFICATION, PRODUCTION, MARKETING, BUYING

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SPECIFIC GRAVITY

I. GENERAL DISCUSSION.

The quantity of matter in a given space is referred to as DENSITY. Expressed scientifically, it is the mass of any substance contained in unit volume. Thus the mass, or quantity, of matter contained in a cube of lead is much greater than that contained in a cube of wood of the same size. The densities of gemstones depend on the closeness with which their atoms are packed and on the weight of those atoms. A one-carat diamond is much smaller than an amethyst (quartz) of the same weight. To say that a diamond is heavier than an amethyst conveys little information; to arrive at an exact comparison, we must compare the weight of equal volumes of each. Since it would be difficult otherwise to compare volumes accurately, this is accomplished by comparing the weight of each stone with the weight of an equal volume of water. The number of times a stone is heavier than the weight of its own volume of water is called its SPECIFIC GRAVITY (also written S.G. or Sp.Gr.). Thus the specific gravity of a gemstone is the ratio of its density to the density of water.

Specific gravity is technically defined as the ratio obtained by dividing the weight of a body by the weight of an equal volume of distilled water at a temperature of 4° C. (39.2° F.). Water at 4° C. has a maximum density and hence can be used as a standard, but in gem testing it is usually possible to obtain sufficiently accurate results without considering temperature.

The specific gravity of quartz is 2.66, which means that a quartz gem of a given size weighs 2 and 66/100 times as much as a volume of water of the same size. Specific gravity is represented by a number that is definite for each species, within certain narrow limits. Hence its determination offers a sure and ready test in the identification of unmounted fashioned gems without injuring them.

Specific gravity is an important property, not only for the purpose of identification, but because of its effect on the relative size per carat of gems. For example, a one-carat emerald is considerably larger than a one-carat diamond, which, in turn, is larger than a one-carat zircon. Stated another way, the higher the S. G., the smaller the stone per carat, and vice versa. For this reason, when replacing a setting in a ring, a jeweler must give the stone's size in millimeters rather than in weight, if he is replacing the original stone with one of another species. Many jewelers become adept at estimating the weight of a diamond by appearance; few, however, are equally proficient in estimating the weight of colored stones. To do so requires a general idea of the relative specific gravities of the various stones. As a further example, a one-carat amethyst is much larger--in fact, perhaps two-thirds greater in diameter--than a zircon of equal weight.

II. THE DETERMINATION OF SPECIFIC GRAVITY.

There are two principal methods of determining specific gravity.

A. The Direct-Weighing Method.

From the definition: specific gravity is equal to the weight of a stone divided by the weight of an equal volume of water. The weight of a stone can be found readily by weighing on an accurate balance. The weight of an equal volume of water can be found by the simple principle discovered by Archimedes, which states that "if a body is totally immersed in water, it loses an amount of weight equal to the weight of the water it displaces." Hence the weight of an equal volume of water is equal to the weight lost by the stone when immersed. Thus:

$$\text{S.G.} = \frac{\text{Weight in Air}}{\text{Weight in Air} - \text{Weight in Water}}$$

In other words, the specific gravity of a stone is the number obtained by dividing its weight in air by its loss of weight when weighed in water. This gives a simple method of finding the S.G. of a cut stone.

In further explanation:

(1) Weigh the stone in air; assume this is 4.2 carats.
(2) Weigh the stone in water; assume this is 3.0 carats.
(3) The difference in the two weighings gives the loss of weight in water: loss of weight = 4.2 - 3.0 = 1.2 carats.
(4) S.G. of stone = weight in air divided by loss of weight in water: S.G. = 4.2 ÷ 1.2 = 3.5.

(Note that the S.G. is a number that represents a RATIO, not a weight.)

For making S.G. determinations by the direct-weighing method, a delicate balance, such as a good diamond balance, is needed. Weighing the stone in air is simple, but to obtain an accurate weight in water is a slightly more complicated undertaking. The problem is how to weigh the stone in water with a minimum of time and equipment. The balance must be adapted so that the stone can be weighed accurately in air and in water. This is accomplished by using a few simple attachments consisting of two thin wires, a glass beaker, and a suitable support. These accessories can be constructed easily or purchased by those who have a diamond balance and who wish to add the necessary equipment.

The small metal support is bridged over one balance pan, so that it does not interfere with the free swing of the balance. The beaker of water is then placed on this stand and one of the thin wires is bent to form a basket at one end to hold the stone. This is suspended from one arm of the balance and immersed in the liquid. The other wire is suspended from the opposite arm of the balance and then clipped or filed off until it balances exactly the wire suspended in the water.

The surface tension of the water acting on the wire at the point where it enters the water causes a damping effect (drag) on the free swing of the balance. This considerably reduces the accuracy normally obtained from the balance. However, a detergent such as "Dreft," "Vel" or "Tide" effectively reduces the surface tension of water, and the pinch or two necessary does not alter the density of the water sufficiently to require a correction factor. The proper temperature for the distilled water used in the direct-weighing method is, as previously mentioned, 4° C., or about 40° F. However, using water at ordinary room temperature of about 70° F. will not materially affect the calculation.

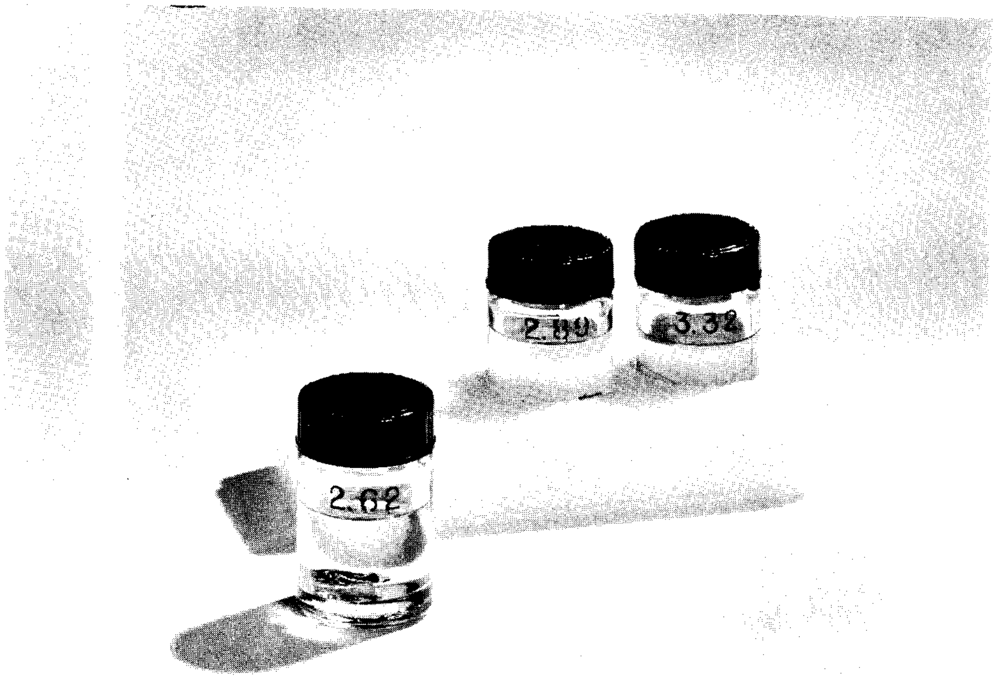
The following example will make the method clear. Given a yellow stone to test:

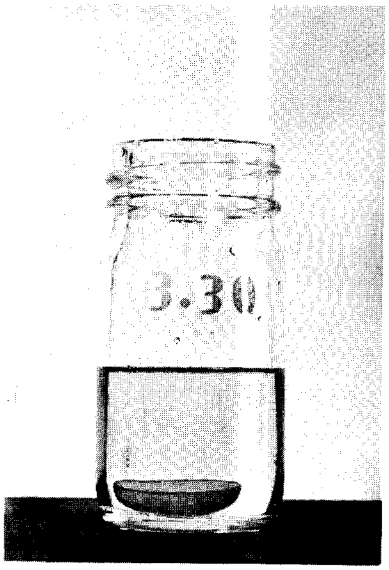
(1) Weight of the stone in air = 12.89 carats.
(2) Place the stone in the wire cage, remove all bubbles, and see that it is completely immersed. Now weigh the stone carefully in water. It weighs 9.67 carats.
(3) Loss of weight in water = 12.89 - 9.67 = 3.22 carats.
(4) S.G. $= \frac{12.89}{3.22} = 12.89 \div 3.22 = 4.00$.
(5) Looking up this value in the accompanying table, we see that the stone is probably yellow sapphire (corundum), either natural or synthetic.

It will be noted in the table that normal S.G. values as well as the most generally encountered variations are listed. However, no tolerance is considered for mechanical errors in making S.G. determinations. There is a definite lower limit in the weight of the stone being tested to which diamond-balance determinations can be given any accuracy.

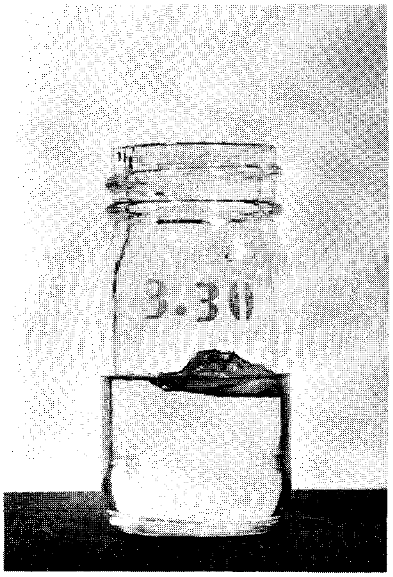
A colored mineral usually varies in specific gravity from one specimen to another, due particularly to slight variations in chemical composition. Therefore, several similar minerals may have the same S.G. because their values overlap, as seen in the table. The values for specific gravity in all mineralogy texts and in some gemology texts are for ALL varieties of a given mineral species. Such tables may add unnecessarily to the confusion of the gemologist who is using them and who needs to consider only gem qualities of the various

Heavy Liquids for Specific-Gravity Determinations

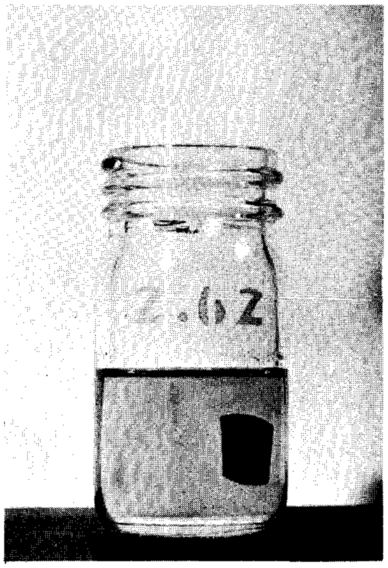




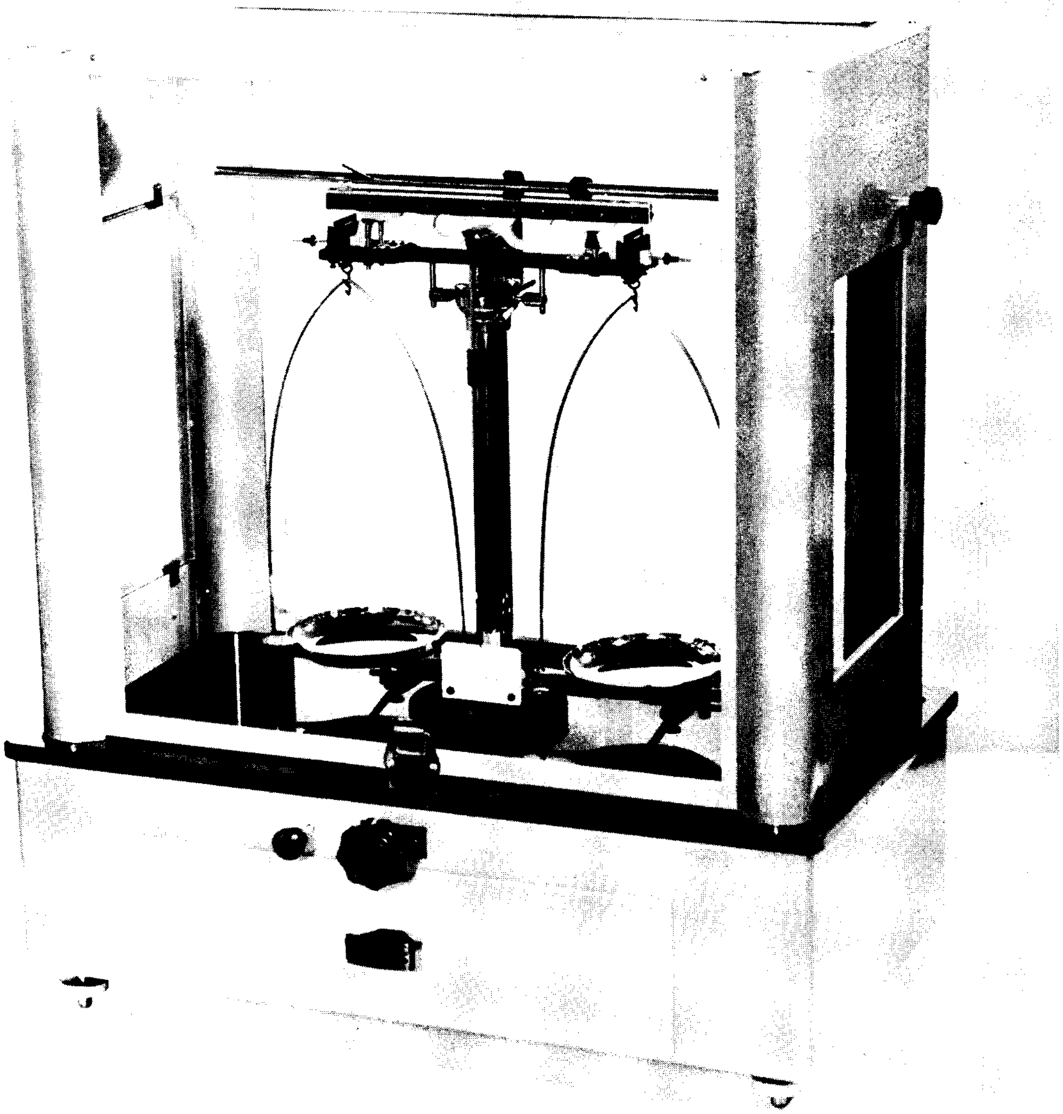
Stone Sinks in Liquid Less Dense Than Itself

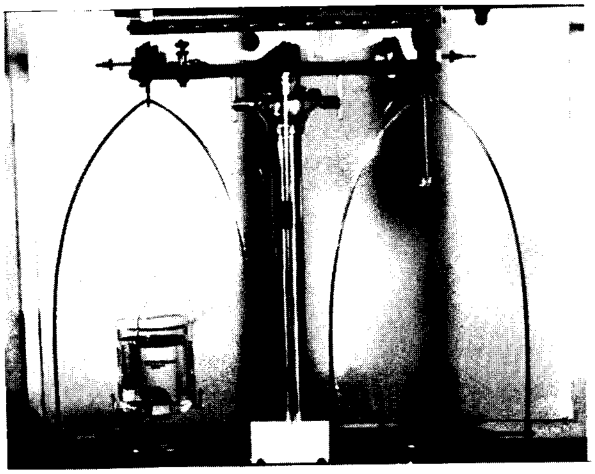


Stone Floats in Liquid More Dense Than Itself



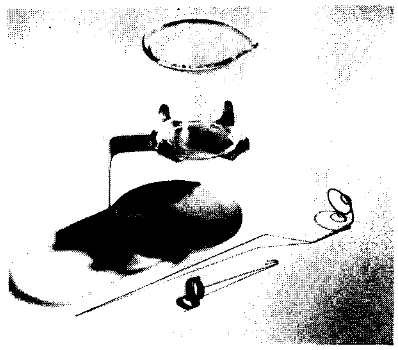
Stone Remains Suspended in Liquid of Same Density as Itself





Diamond Balance

Specific-Gravity Attachments for Diamond Balance



species. The figures in the table are for gem materials, and show specific gravity to be one of the more important tests.

To illustrate the effects of errors in weighing, refer again to the example given above. The weight of the stone in air is 12.89 carats and its weight in liquid is 9.67 carats. Suppose a mistake of one point had been made in weighing the stone in liquid. If the weight had been 9.66 instead of the correct 9.67 figure, the difference between 9.66 and 12.89 is 3.23 carats. By dividing 3.23 into 12.89, a specific-gravity determination of 3.99 is made. Therefore, an error of only .01 occurs because of a mistake of one-hundredth of a carat in the weight. A stone that weighs 1.20 carats in air and 90 points in water would have an S.G. of 4.00. If, however, a mistake is made in the weighing and the weight in water is determined as .89 carats instead of .90, the error will be greater. Dividing 1.20 by .31 gives a resulting S.G. of 3.87; therefore, the error is .13. Carrying this example one step further, if a stone weighs .40 carats in air and .30 carats in water, it has a specific gravity of 4.00. An error in this case of one point, giving a water weight of .29, would result in the determination being 3.63 to 3.64. In other words, an error of more than .35 in S.G. would result.

From the above discussion, it can be seen that specific-gravity determinations by the diamond-balance method for stones of less than one-half carat are not accurate unless very careful weighings are made. No such limitation exists when heavy liquids are used instead of the diamond balance.

B. Heavy Liquids.

When a solid is placed in a liquid of lower density, it sinks. On the other hand, if its density is lower than that of the liquid, it floats, as does wood in water. If a stone has an S.G. equal to the density of the liquid into which it is dropped, it remains suspended in the liquid. This would have no particular significance if it were not for the availability of a number of liquids with densities up to several times that of water. The advantage of a heavy liquid is that it is so simple and free from the potentiality of arithmetical error. In addition, it provides a very fast method.

Although the obvious findings of the heavy liquids are simply whether the stone has a higher or lower S.G. than the liquid, more information may be gained. As a stone sinks in a liquid, an idea of how much more dense it is than the liquid is furnished by observing how rapidly it sinks. This is affected also by the shape of the stone. For example, a large flat stone will sink more slowly in the flat position than in an upended position. When a stone floats, the percentage above and below the liquid represents the relationship between the two S.G's. In other words, if the stone has 9/10 of its volume beneath the surface, it has an S.G. equal to 9/10 that of the liquid. The exact ratio can be estimated only roughly by eye, but it serves as a guide.

Unfortunately, the heavy-liquid method has a major limitation (in addition to the one that any S.G. method suffers: the restriction to loose stones only), and that is the practical upper limit for safe liquids at 3.32. Above that figure, those that are readily available are either opaque suspensions of finely divided solids in a heavy liquid or Clerici's solution. The latter is poisonous and corrosive, so it is dangerous unless used with caution.

TABLE OF SPECIFIC GRAVITIES OF VARIOUS LIQUIDS

LIQUID	SPECIFIC GRAVITY
Saturated salt solution	1.15
Carbon tetrachloride	1.59
Bromoform	2.89
Methylene iodide	3.32
Thallium formate and malonate (Clerici's solution)	4.65
Thallium silver nitrate	5.00

A very useful set of heavy liquids consists of three small bottles or beakers, each containing about 25 cc. of a heavy liquid. The first bottle contains methylene iodide (3.32), the second contains bromoform (2.89), and the third bottle contains bromoform diluted with xylene (2.62). By dropping the unknown stone first into one and then into the other liquid (being careful to wipe the stone thoroughly to avoid contamination of one liquid by another), it is possible to place it into one of the following four broad groups:

(1) Floats in 2.62 liquid.
(2) Sinks in 2.62 liquid and floats in 2.89 liquid.
(3) Sinks in 2.89 liquid and floats in 3.32 liquid.
(4) Sinks in 3.32 liquid.

If desired, additional liquids having intermediate S.G.'s may be prepared by diluting pure methylene iodide or bromoform with different amounts of xylene and using the following gems as indicators to calibrate the liquids: moonstone (2.56), quartz (2.66), aquamarine (2.72), nephrite (2.95), tourmaline (3.06), kunzite (3.18). The methylene iodide or bromoform is diluted until one of these gems remains suspended in the liquid. However, since xylene evaporates more rapidly than either of the other chemicals, the bottles should be kept tightly stoppered if the liquids are to remain constant. In addition, the indicators should be left in the bottles at all times so that an immediate visual check of the value of the liquids can be made.

Because of the low cost and the rapidity with which reasonably accurate determinations can be made, a set of heavy liquids should be one of the first acquisitions for any gem-testing laboratory. Of course, for a wider range of S. G.'s, the direct-weighing method with the diamond balance is necessary.

III. OTHER METHODS OF OBTAINING SPECIFIC GRAVITY.

The Jolly balance, the Berman balance and the Newton scales are other instruments used to obtain specific gravity. Although used on occasion by mineralogists, these instruments are of little value to the gemologist. For the interested student, complete descriptions can be found in any standard mineralogical text.

OTHER PHYSICAL PROPERTIES

I. THE EFFECTS OF HEAT.

When placed before the flame of the blowpipe, some minerals fuse entirely, whereas only the surface consistency of others is affected. The results are used in the identification of rough minerals. Such methods are useless in identifying fashioned gemstones, since their beauty and value would be partly or wholly destroyed. However, it is very important for the repairman to be familiar with the effects of heat on various gemstones.

Of the important gem minerals, turquois, emerald, garnet, quartz peridot, zircon and tourmaline are likely to crack under heat unless well protected from direct blowpipe flame and cooled slowly. Turquois is so vulnerable to direct heat that even the low temperature produced by a burning match may cause it to fly into many pieces. Fortunately, other gemstones are not as easily damaged by heat. In addition, a number of stones are likely to change color when heat is applied. These include amethyst, aquamarine, zircon, tourmaline and topaz. If subjected to sufficiently high temperatures (about 900° C.) for a long enough period, diamond will first cloud and then blacken on the surface, and may even be totally destroyed by burning up.

From the number of stones affected, it can be seen that it is important for the repairman to be careful when sizing rings and doing other types of repair work involving the use of heat.

II. THE EFFECTS OF CHEMICALS.

Certain elements or combinations of elements, especially acids, have a visible effect on the surface of certain minerals, and more especially on the powder of a mineral. The effect of such chemicals is used to great advantage in identifying rough minerals, but would affect the beauty and value of a fashioned gem.

Hydrofluoric acid is sometimes recommended as a test. It dissolves glass but etches the surface of the quartz gems; therefore, it is of value only when the stone has already been proven not to be genuine. Although a number of gemstones are affected by acids, most transparent stones are affected very little. Many of the translucent and opaque stones are affected materially. Both natural and cultured pearls are dissolved by hydrochloric and some other acids. All acids affect pearl, coral, malachite, azurite and turquois. The effect of hydrochloric acid is sometimes used to separate imitation pearls from cultured and natural pearls. A drop of the acid on any pearl will cause strong effervescence but will not affect the imitation. Since the acid will damage a pearl unless applied in a minute droplet and removed quickly, extreme care must be exercised in using the test.

III. FEEL.

Some minerals may be recognized by their feel, but the highly polished surfaces of gems so greatly lessens the possibility of using feel for identification that it is only mentioned in connection with a few stones: jade (greasy), topaz (usually slippery), pearl (gritty to the teeth), some chalcedony (adheres to the tongue). Those who experiment over a number of years may develop a valuable sense of feel.

IV. ODOR.

Some minerals have characteristic odors reminiscent of garlic, horseradish, sulphur, resin, etc., when heated, rubbed, breathed upon or struck. Rarely, however, does odor prove valuable in gem testing. Almost the only use is in distinguishing between amber and its substitutes.

V. MAGNETISM.

A very few minerals in their natural state are capable of being attracted by a strong steel magnet; they are often said to be magnetic. These minerals are seldom of gemological importance. Hematite is sometimes slightly magnetic, but this is probably due to a small admixture of magnetite, which has the property of being attracted by a magnet. Magnetite, pyrrohotite and some varieties of native platinum are magnetic. The variety of magnetite known as LODESTONE exhibits the attracting power and polarity of a true magnet. These are sometimes called "natural magnets," and are occasionally used for pocketpieces.

VI. ELECTRICITY.

An electrical charge can be developed in many substances and, in some degree, in all minerals by either friction or heat. Electricity developed by heat is called PYROELECTRICITY. Tourmaline is pyroelectric, and topaz and amber are examples of materials that become highly electrified by friction.

VII. FLUORESCENCE AND PHOSPHORESCENCE

Some minerals, when exposed to invisible ultraviolet or cathode rays, will emit visible light. This property is known as FLUORESCENCE. It is named from the mineral fluorite, which often displays the phenomenon to a marked degree. Almost every genuine or synthetic ruby fluoresces a bright red when exposed to ultraviolet light. When the glow continues, or "coasts," after the exciting rays have been cut off, the phenomenon is known as PHOSPHORESCENCE.

Many diamonds fluoresce in ultraviolet light and some will phosphoresce. The significance of fluorescence in diamonds lies in the fact that most of the stones that do glow under ultraviolet light exhibit a blue color. The presence of ultraviolet in daylight causes diamonds that fluoresce a strong blue to take on a blue cast that is not evident in artificial light (which lacks ultraviolet). Thus diamonds that fluoresce blue have a much better color in daylight than in artificial light. Some jewelers have used this property to advantage in creating interest in diamonds. Although it has little effect on value, it does make some customers feel that their diamond is unusual and unlike those of their friends.

Since various gemstones react differently under ultraviolet light, characteristic fluorescence can sometimes be used as a means of identification. Usually, however, it is used more as an indication of identity rather than as a means of conclusive identification.

SPECIFIC GRAVITY OF THE COMMON GEM MINERALS AND RELATED SUBSTANCES

The gem materials listed in this table may be divided roughly into three groups: (1) low S.G. (below 2.90), (2) medium S.G. (between 2.90 and 3.55), and (3) high S.G. (above 3.55). Most gem species vary in specific gravity depending on inclusions, faulty structure, variation of accidental impurities causing color, or other irregularities in formation. The "Normal" figure given here is the usual S.G. The figures in the "Variation" column represent the most generally encountered S.G. range of the substance under consideration; corundum, for example, has a gravity of 4.00 but can vary from 3.97 to 4.03.

Gem	Normal	Variation
Hematite	5.20	5.12 to 5.28
Pyrite	5.00	4.90 to 5.10
Marcasite	4.85	4.80 to 4.90
Zircon (High)	4.70	4.67 to 4.73
Zircon (Med.)	4.32	4.07 to 4.57
Syn. Rutile	4.26	4.24 to 4.28
Spessartite (G)	4.15	4.12 to 4.18
Almandite (G)	4.05	3.93 to 4.17
Zircon (Low)	4.00	3.93 to 4.07
Corundum	4.00	3.97 to 4.03
Syn. Corundum	4.00	3.97 to 4.03
Andradite (G)	3.84	3.81 to 3.87
Rhodolite (G)	3.84	3.74 to 3.94
Pyrope (G)	3.78	3.62 to 3.87
Chrysoberyl	3.73	3.71 to 3.75
Syn. Spinel	3.65	3.61 to 3.69
Grossularite (G)	3.61	3.57 to 3.73
Spinel	3.60	3.57 to 3.90
Topaz	3.53	3.49 to 3.57
Diamond	3.52	3.51 to 3.53
Peridot	3.34	3.32 to 3.48
Jadeite (J)	3.34	3.30 to 3.38
Spodumene	3.18	3.15 to 3.21
Tourmaline	3.06	3.01 to 3.11
Nephrite (J)	2.95	2.90 to 3.00
Turquois	2.76	2.61 to 2.84
Lapis-Lazuli	2.75	2.50 to 3.00
Shell	2.73	2.70 to 2.76
Beryl	2.72	2.67 to 2.84
Pearl	2.70	2.68 to 2.85
Labradorite (F)	2.70	2.65 to 2.75
Quartz	2.66	2.65 to 2.66
Syn. Emerald	2.66	2.65 to 2.68
Oligoclase (F)	2.65	2.63 to 2.67
Coral	2.65	2.60 to 2.70
Chalcedony (Q)	2.60	2.55 to 2.65
Orthoclase (F)	2.56	2.55 to 2.57
Microcline (F)	2.56	2.55 to 2.57
Glass	Varies	2.30 to 4.50
Opal	2.15	2.07 to 2.23
Jet	1.32	1.30 to 1.34
Plastics	1.30	1.05 to 1.55
Amber	1.08	1.06 to 1.10

Key to Symbols: (G) = Garnet (F) = Feldspar (J) = Jade (Q) = Quartz.

UNITS OF WEIGHTS AND MEASUREMENTS

The following table lists the units of weights and measurements most commonly employed in the jewelry trade, together with certain other units possessing interest value only. Each unit named is followed by its correct abbreviation (in parentheses) and its equivalent in one or more units of the same quantity.

1 Carat (c. or ct.) = ... 0.00705478 oz.av. = 100 "Points" = 1/5 g. = 200 mg. = 3.08647 gr. = 4 pearl grains.

1 Pennyweight (dwt.) = ... 0.003428571 lb.av. = 0.0041667 lb.t. = .05 oz.t. = 0.0548571 oz.av. = 24 gr. = 1.55517 g. = 1,555.17 mg.

1 Pearl Grain = ... 1/4 ct.

1 Kilogram (kg.) = ... 2.20462 lb.av. = 2.6792285 lb.t. = 32.15076 oz.t. = 35.273957 oz.av. = 643.01 dwt. = 15,432.35639 gr. = 1,000 g.

1 Gram (g.) = ... 0.03527 oz.av. = 0.03215 oz.t. = 0.6430 dwt. = 15.4324 gr. = 0.001 kg. = 5 ct. = 1,000 mg.

1 Milligram (mg.) = ... 0.015432 gr. = 0.001 g. = 0.005 ct.

1 Millimeter (mm.) = ... 0.0393700 inch.

1 Grain (gr.) = ... 0.0020833 oz.t. = 0.0022857 oz.av. = 0.041667 dwt. = 0.0648 g. = 0.3240 ct. = 64.798918 mg. (Note: the grain troy equals the grain avoirdupois.)

1 Pound Troy (lb.t.) = ... 0.822857 lb.av. = 12 oz.t. = 13.1657 oz.av. = 240 dwt. = 5,760 gr. = 0.3732418 kg. = 373.24177 g. = 1,866.12 cts.

1 Ounce Troy (oz.t.) = ... 1.09714 oz.av. = 20 dwt. = 480 gr. = 31.103481 g. = 155.51 ct.

1 Pound Avoirdupois (lb.av.) = ... 1.21528 lb.t. = 14.5833 oz.t. = 16 oz.av. = 291.667 dwt. = 7,000 gr. = 0.4535942 kg. = 453.5924 g. = 2,267.962 cts.

1 Ounce Avoirdupois (oz.av.) = ... 0.9114883 oz.t. = 18.22917 dwt. = 437.5 gr. = 28.3495 g. = 141.75 ct.